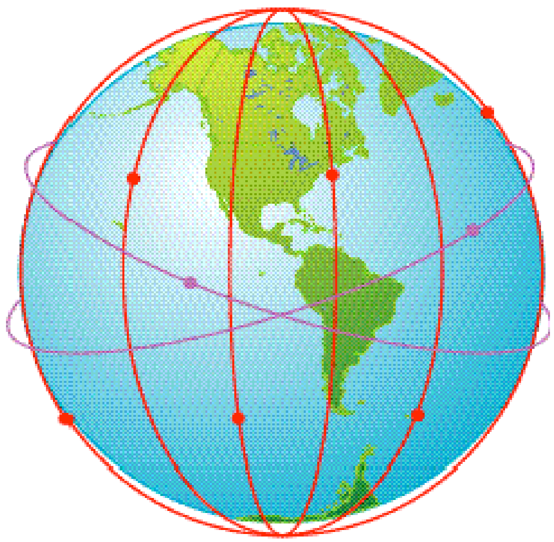
Ionospheric Mappers

Report for the Splinter Session

In situ satellites at 450 km circular orbits

6 Polar orbiting satellites

2 Low inclination (e.g., 30˚) satellites



- Attendance: ~30
- All Agencies Present
- [Rob Pfaff used only 2 minutes]
- 40 constructive questions-answers-comments during 1.75 hr meeting.
- Good natured group.

Reporter: Jan J. Sojka, USU

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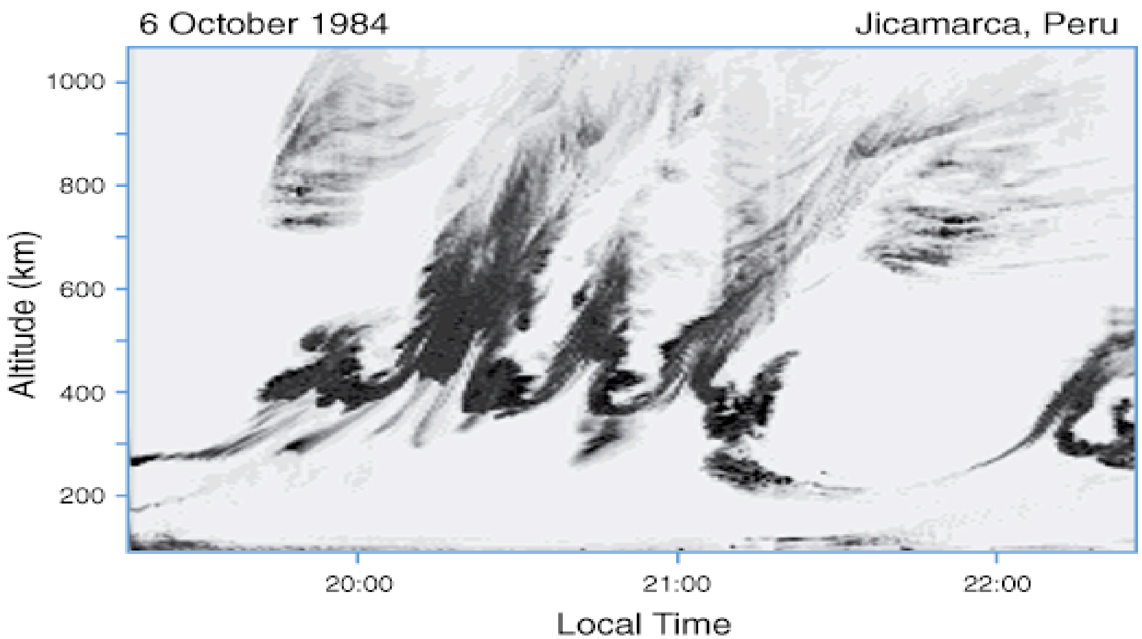

Robert F. Pfaff
NASA/GSFC Code 696

Living With a Star -- Community Workshop
May 10-12, 2000

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Space Weather Effects -- Why do we care about the ionosphere?

I. Human presence in space (e.g., Shuttle, Space Station, High Altitude Aircraft)

- Solar and magnetospheric high energy radiation are hazardous to astronauts.
- Space station, EVA astronauts, "portable" satellites may undergo dangerous differential charging.

II. Impacts on Technology

Communications and Navigation

- HF and other frequencies disrupted by scintillations created by irregularities.
- Maximum Useable Frequency determined by plasma density along path.
- GPS position errors are function of ionospheric density irregularities, scintillations.

Satellite Systems and Space Technology

- Can be highly susceptible to radiation and charging effects, resulting in loss of spacecraft.

Orbital Drag — collision avoidance, re-entry, orbital debris

- Low earth orbit satellites may re-enter due to increased drag, including "abrupt" variations.

Currents in Space

- Induced currents in long, ground-based conductors may disrupt power grids.

III. Global Climate Change

- Quantitative measurements needed to assess both long and short term climate evolution.

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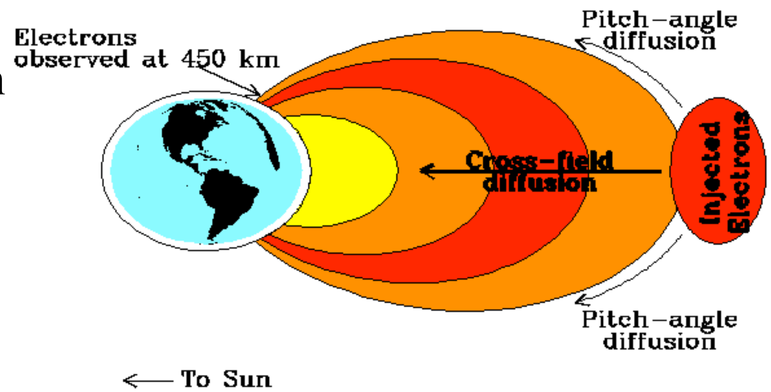
Problem: Energetic Particle Radiation are Hazardous to Astronauts

Need To Know:

1. Spatial and temporal distribution of radiation
2. Relation to magnetospheric drivers
3. Geographic distribution (e.g., South Atlantic anomaly effects)
4. Lifetime of particles and impulsive effects
5. Geomagnetic latitude cutoff



Approach: Simultaneous observations on multiple platforms at the altitude of the space station in concert with Radiation Belt Mappers observations of driving processes.

Energies of interest:	Electrons	0.1–10 MeV (or higher)
	Protons	0.1–500 MeV

Detectors must have adequate pitch angle coverage with sufficient energy resolution.

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- IM complements the Radiation Belt Mapper (RBM) mission by carrying high energy particle detectors package.
- IM at 450 km orbit would enable measurements to be made for RBM to verify and/or validate the RBM radiation belt science and 'product' development.
- IM would, through its 6 polar orbits, spread in longitude/LT providing excellent coverage of the South Atlantic Anomaly radiation environment dynamics at LEO.
- IM pre-formation team's selection of an orbit altitude of 450 km was driven by the fact that this is the altitude of the space station and, hence, the radiation environment the space station crew would be exposed to.

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Problem: Atmospheric Drag May Cause Satellites to Re-enter Prematurely

Background: Atmospheric density in the ionosphere is strongly dependent on solar activity. Difficult to specify and predict neutral density variations.

Need To Know:

1. Spatial and temporal distribution of neutral density and neutral scale height.
2. Sources of abrupt variations in neutral density and temperature.
3. Detailed relation of neutral density variations and solar output.

Approach:

- Measure neutral density and composition on multiple platforms around globe.
- Measure drag on each satellite to obtain scale height of atmosphere.
- Combine density and scale height measurements to create neutral density profile vs. altitude.

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- IM would advance knowledge of Atmospheric Drag (AD) to practical LWS-user level.
- Two new science issues associated with AD were raised, i.e., new results:
  1) Upper atmosphere (LEO) shows a 14-day oscillation? Why? Not seen at E-region heights.
  2) Atmosphere appears to be surprisingly sensitive to FU; does this appear in AD?
- IM will provide excellent global mapping of the neutral density and composition which is AD.
- IM will also acquire high quality coverage of the ionosphere-thermosphere drivers and their specification. This will drive models. In turn, comparisons with AD measurements (prior item) will lead to new understanding of I-T physics and AD.
- IM at 450 km will provide observation and explanation of space station drag variability.

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Problem: Scintillations

Background

- Ionosphere contains large amplitude variations over spatial scales from cm to 100's of kms.
- VHF/UHF communications as well as automated navigation and precision positioning via GPS are affected by scintillations.
- Low-latitude scintillations are greatest cause of GPS position errors.
- High-latitude scintillations are related to patches and blobs of plasmas.
- Mid-latitude irregularities cause scintillations of lower amplitude.

Approach:

- Measure electron density with global coverage.
- Use sounders to electron N_e, h_mF_2 altitude, and regions of scintillations.
- In situ plasma wave measurements to map drivers.
- GPS receivers to map scintillations and provide tomographic mapping.

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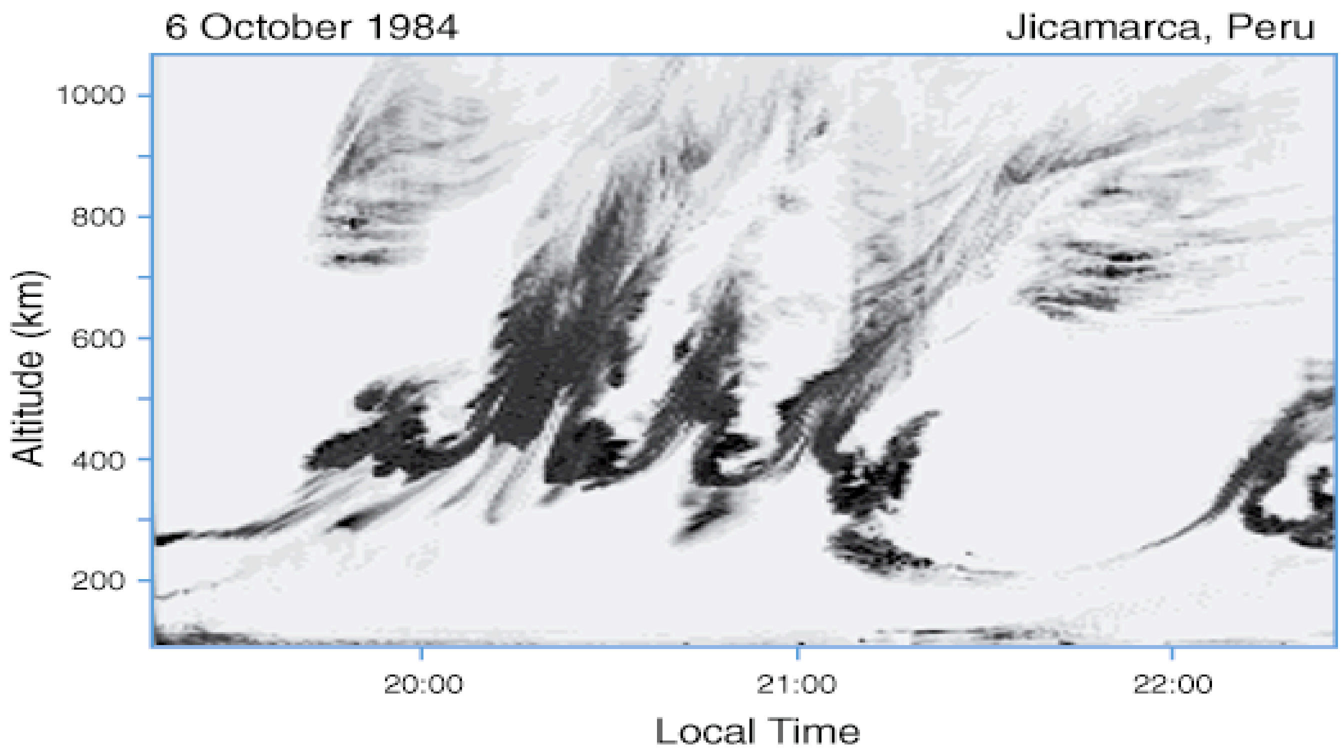

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The prior rendering of ionospheric irregularity data observed at the equator by a radar was discussed. Differing views on it:

a) It should not be used since IM cannot possibly resolve all the structure scales being shown.

b) It should be used because it demonstrates the multi-scale of a key LWS phenomena, ionospheric irregularity leading to scintillation, and hence educates a reader on the complexity of the problem. This is similar to showing a dynamic solar image with multiple scale structures.

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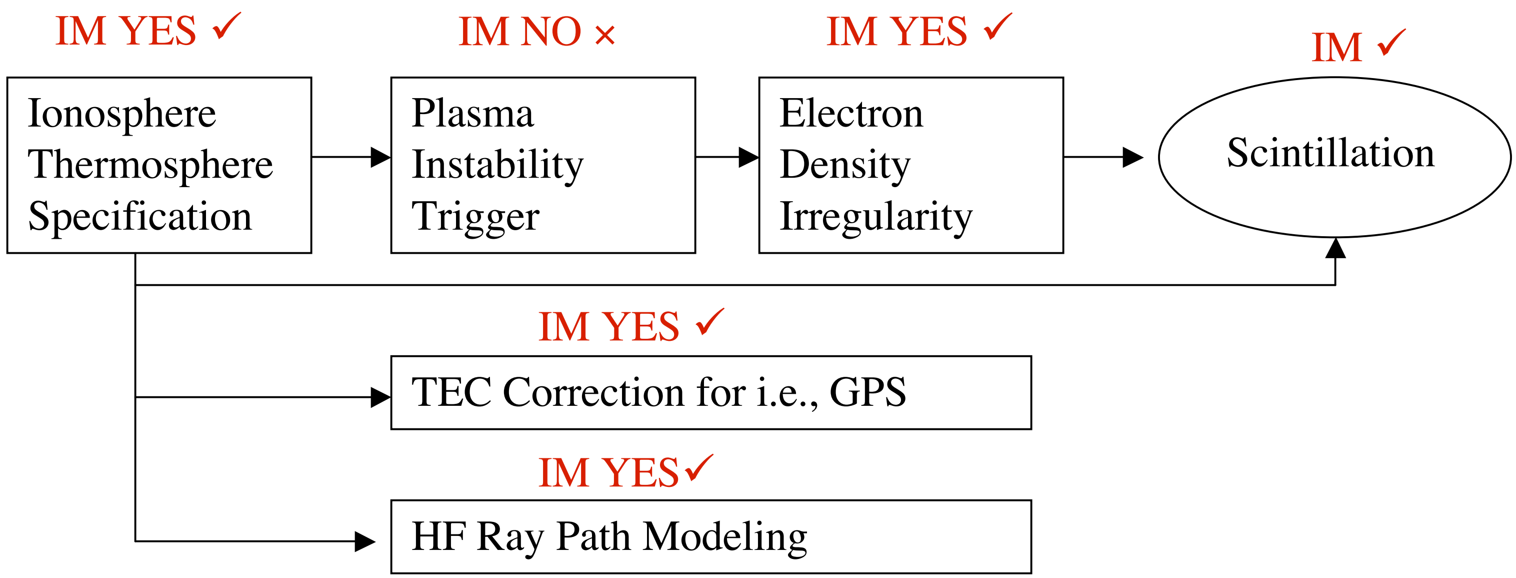
- The LWS scintillation issue received significant discussion.
- It is a major user problem.
- The key science question of, “what is the trigger for the growth of instabilities leading to scintillations,” will probably not be “seen” by IM.
- Instead, IM will accurately characterize the Ionosphere-Thermosphere in which the instability grows. This is a necessary next step in understanding the physics involved.
- Together with IM irregularity measurements, an empirical model approach may provide new tools for scintillation specification and forecast.



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- A challenge for LWS or proof of concept was stated as follows:

  > "When the satellites (IM) are not flying, will we have improved the understanding/user models?"
  >
  > – Bob Robinson (NSF)

- Although not explicitly stated in the form of the four quadrant science-technology map of Bohr, Pasteur, Edison, and "Bart Simpson," the above question is intended to keep LWS wary that as scientists go from the Bohr to Pasteur quadrant and technologists from the Edison to Pasteur quadrant, we do not fall into the "Bart Simpson" quadrant.

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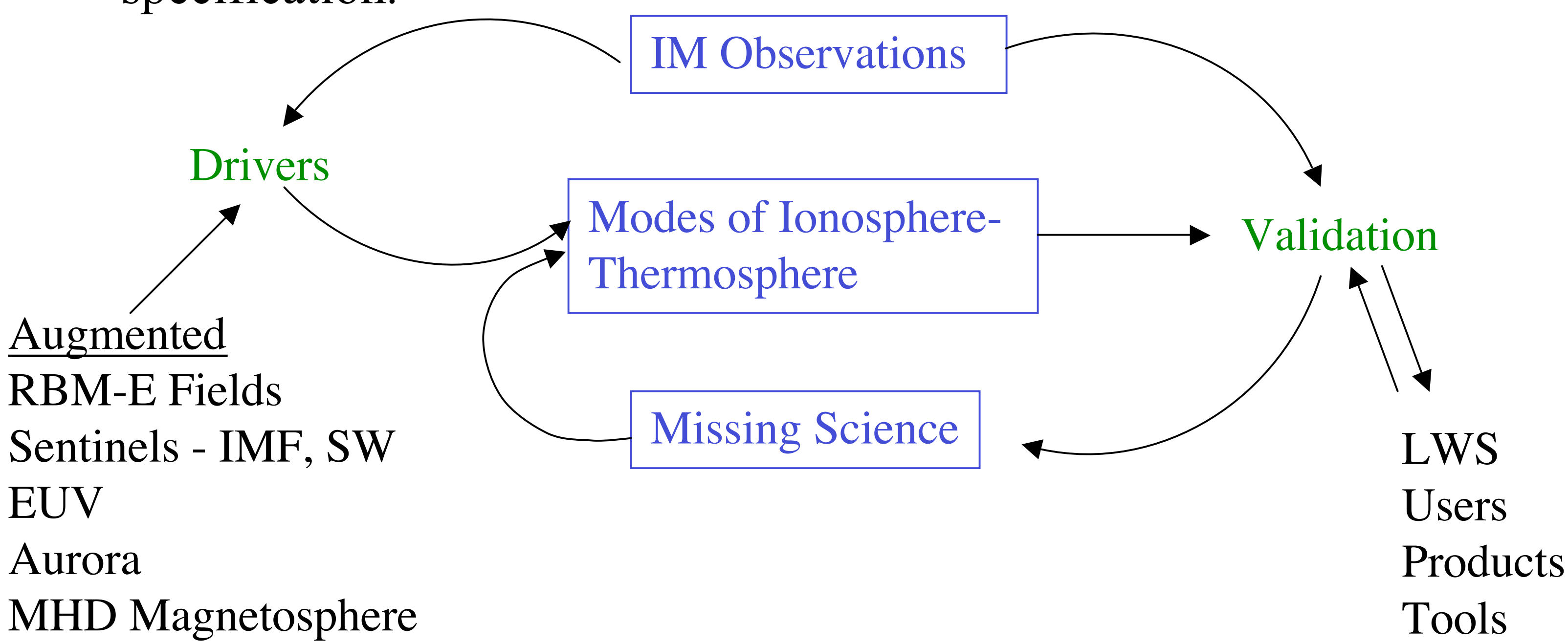
- Ionospheric specification is an area in which models are advanced but incomplete and, most of all, these models need data.
- IM provides drivers, augmented by other sources, for models.
- But, IM also provides the unique global specification of the ionosphere (thermosphere) the model outputs.
- IM will provide a prototype of LWS system for ionospheric specification.



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- What is IM configuration in detail?
- How many satellites? Which orbits?
- Which altitudes?
- A repeated return to these issues occurred during the meeting. All altitudes from 150 to 1000 km are relevant to the ionosphere LWS work. Pre-formulation chose 450 km because of its synergism to Space Station orbit and radiation environment.
- The future IM Science Technology Definition Team (STDT) needs to worry about these issues.

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IM and Real Time Data

- The pre-formulation team did not want continuous real-time data to be a cost driver and provided the following solutions for users:
  1) Each IM satellite can be commanded by a ground station to dump data as the satellite flies over.
  2) The ground station could be a "user provided" station.
  3) A user data format would be accommodated on each satellite to ensure users receive only the data they need during these downloads.

- The users represented by DoD, NOAA, and other interested parties indicated that this would meet their perceived needs.

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Extended, Recurring, Discussion Topics

- IM will not be alone.

  NASA and other agencies will have solar terrestrial observing systems: GPS + Cosmic, DMSP (+ follow-ons), GEC, possibly MMS or MagCon, SDO, Sentinels, "L1 monitor," RBM later, etc.

  Hence, as IM develops, there is a natural synergism for the LWS program data, modeling, users to take advantage of these resources and maximize the LWS output both scientifically and technically.

- Not everything may be monitored. The short list needed by many users and scientists consists of (IMF solar wind), (FUV/EUV), aurora, . . .
  - At present, ACE does IMF solar wind
  - At present POLAR IMAGE does aurora
  - A future NOAA satellite may do FUV/EUV?

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Summary

- The splinter working group found the IM pre-formulation plan to address the appropriate science and user needs in the ionosphere.

- They also indicated the ionosphere environment is rich in competing user needs (i.e., hence distribution, selection, etc., issues) and the pre-formulation plan attempted to do justice to many if not all the key issues. This probably is over ambitious and a down select of a more specific science user objective for IM will be done by the future STDT.

- In so doing, the IM will readily meet the LWS overall goals including cost and technical acceptability.